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Relativistic Electron Precipitation Patterns
in Longitude and Latitude: A Reply to
W. R. Sheldon, Et Al.

D. N. BAKER
Goddard Space Flight Center
Greenbelt, MD 20771

J. B. BLAKE and D. J. GORNEY
Space Sciences Laboratory
Laboratory Operations
The Aerospace Corporation
El Segundo, CA 90245

P. R. HIGBIE, R. W. KLEBESADEL, and J. H. KING
Los Alamos National Laboratory
Los Alamos, NM 87545

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SPACE DIVISION
AIR FORCE SYSTEMS COMMAND
Los Angeles Air Force Base
P.O. Box 92960
Los Angeles, CA 90009-2960

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CLARENCE V. WILCOX, LT, USAF
MOIE Project Monitor
SD/CLTPC



JAMES A. BERES, LT COL, USAF
MOIE Program Manager
AFSTC/WCO OL-AB

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| <p>In an earlier paper by the authors, a proposal was made that the precipitation of relativistic electrons from the outer magnetosphere into the Earth's atmosphere could have substantial effects on the chemistry of the middle atmosphere. It has been argued that our earlier estimates of precipitation fluxes may have underestimated the precipitation rates in isolated regions, such as the South Atlantic Anomaly, and overestimated the precipitation in other latitude and longitude sectors. Here, we discuss the factors which influence the longitudinal uniformity of relativistic electron precipitation and the implications of our earlier assumption of uniform precipitation. <i>Keynote</i></p> | | | | | |
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PREFACE

We appreciate very useful conversations with L. B. Callis, M. S. Gussenhoven, and W. R. Sheldon concerning this work. This research was supported by NASA, the U. S. Department of Energy, and by the U. S. Air Force.

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In their commentary, Sheldon et al. (1988) point out that the asymmetry of the geomagnetic field relative to the terrestrial surface and overlying atmosphere leads to exceptionally low mirror altitudes for trapped energetic particles with small equatorial pitch angles in the South Atlantic Anomaly (SAA) region. It has been realized for a long time that this feature of the geomagnetic field can result in a strong geographical localization of electron precipitation. Sheldon et al. (1988) therefore conclude that Baker et al. (1987) may have underestimated the precipitation rate of MeV electrons in the South Atlantic Anomaly and overestimated the electron precipitation rate in other latitude and longitude sectors.

In an earlier version of our paper (Baker et al., 1987), we discussed in some detail the issue of non-uniformity of energetic electron precipitation over the outer zone region. We had explicitly noted that the substantial symmetry in the geomagnetic field could give an enhancement in the relativistic electron precipitation in the Southern Hemisphere. We had discussed also that one would not expect precipitation that results from wave-particle interactions to be uniform in longitude, latitude, local time, or time. It is clear that the intensity and energy spectrum of the precipitating electrons will depend upon these and probably other factors. However, the data necessary to model adequately these aspects in any detail, to our knowledge, do not exist. For this reason we decided to restrict our discussion to the simplest case, that of uniform precipitation in latitude and longitude throughout the outer-zone region, recognizing that it must be a great simplification of the real-world situation.

A few specific comments on the effect of the SAA on electron precipitation can be made. The magnitude of the anomaly in the geomagnetic field is a strong function of latitude; by the time the synchronous orbit region is reached, it is small (Gledhill, 1976). A dependence of precipitation rates upon geographic longitude in the synchronous region, where our measurements were made, is not observed (cf., Vampola and Gorney, 1983). Thus, observations referred to by Sheldon et al. (1988) are not characteristic of the situation throughout the outer zone.

The Defense Meteorological Satellite Program (DMSP) spacecraft have made some measurements relevant to this issue. Since the DMSP spacecraft are in a polar, 840-km altitude orbit, their sensor systems respond largely to precipitating particle populations and to particles near the edge of the equatorial loss cone (Gussenhoven et al., 1987). The DMSP electron dosimeter experiment has provided a long-term monitor of the electron environment above several different energy thresholds. Figure 1 shows a yearly averaged (November 1984 -- October 1985) map of the measured electron dose ≥ 1.0 MeV for the DMSP F7 spacecraft as a function of magnetic latitude and magnetic longitude.

The figure shows quite clearly the strong electron precipitation associated with the SAA: This is the intense patch of energetic particle fluxes extending from 0° to $\sim 40^\circ$ geomagnetic latitude and centered at $\sim 30^\circ$ geomagnetic longitude. [Note that this feature probably also contains a large proportion of high energy protons from the inner zone which are not excluded by the DMSP dosimeter (Gussenhoven et al., 1987).] As stated by Sheldon et al. (1988), the SAA precipitation is a significant feature. However, the DMSP data also show intense bands of >1 MeV electrons at higher latitudes (50° - 70°) and extending rather substantially around the Earth in longitude. These are the relativistic electron features that Baker et al. (1987) documented at higher energies and interpreted as being of middle atmospheric significance. Indeed, the DMSP latitudinal pattern shown is very similar to that used by Baker et al. (1987) for their global energy input calculations.

In a study of the global electron relationship, Higbie et al. (1987) compared daily averages of electron fluxes measured on four different spacecraft platforms. This included the Spectrometer for Energetic Electrons (SEE) ≥ 2 MeV data at $6.6 R_E$ reported by Baker et al. (1987), the >1 MeV DMSP data summarized above in Fig. 1., available ≥ 0.5 MeV electron measurements from the Global Positioning Satellite (GPS) at a $4 R_E$ circular orbit (inclination $\sim 60^\circ$), and >1 MeV electron data from a satellite in a Molniya-type orbit. It was found that virtually every significant flux

peak in the SEE data has its counterpart in the DMSP data. Higbie et al. (1987) noted that this correspondence extended also to the GPS and the Molniya data sets. Hence, it was on this basis that it was concluded that there was a truly global, reasonably homogeneous relativistic electron population in the Earth's outer magnetosphere and that there is a remarkably close temporal correlation between electron fluxes measured at DMSP and at geostationary orbit.

We are presently trying to quantify and extend our understanding of the precipitation of relativistic electrons in the outer magnetosphere. We have been carrying out studies with Callis and coworkers (Callis and Natarajan, 1986; Callis et al., 1988) in an attempt to directly relate changes in the middle atmospheric chemistry to enhancements in outer zone relativistic electrons. Such direct correlations, if they exist, clearly are part of the definitive evidence -- the "smoking gun" -- we seek. We are convinced that data from rockets, balloons, and low-altitude satellites collected on a long-term basis are required to resolve the question of the significance of these relativistic electrons within the context of middle atmosphere-magnetosphere coupling. We believe that observations such as described by Sheldon et al. (1988) will be part of the complete story and that, at lower latitudes, effects of the SAA will appear.

CHANNEL 1 LOLET DOSE CONTOURS
(NOV 1984-OCT 1985)

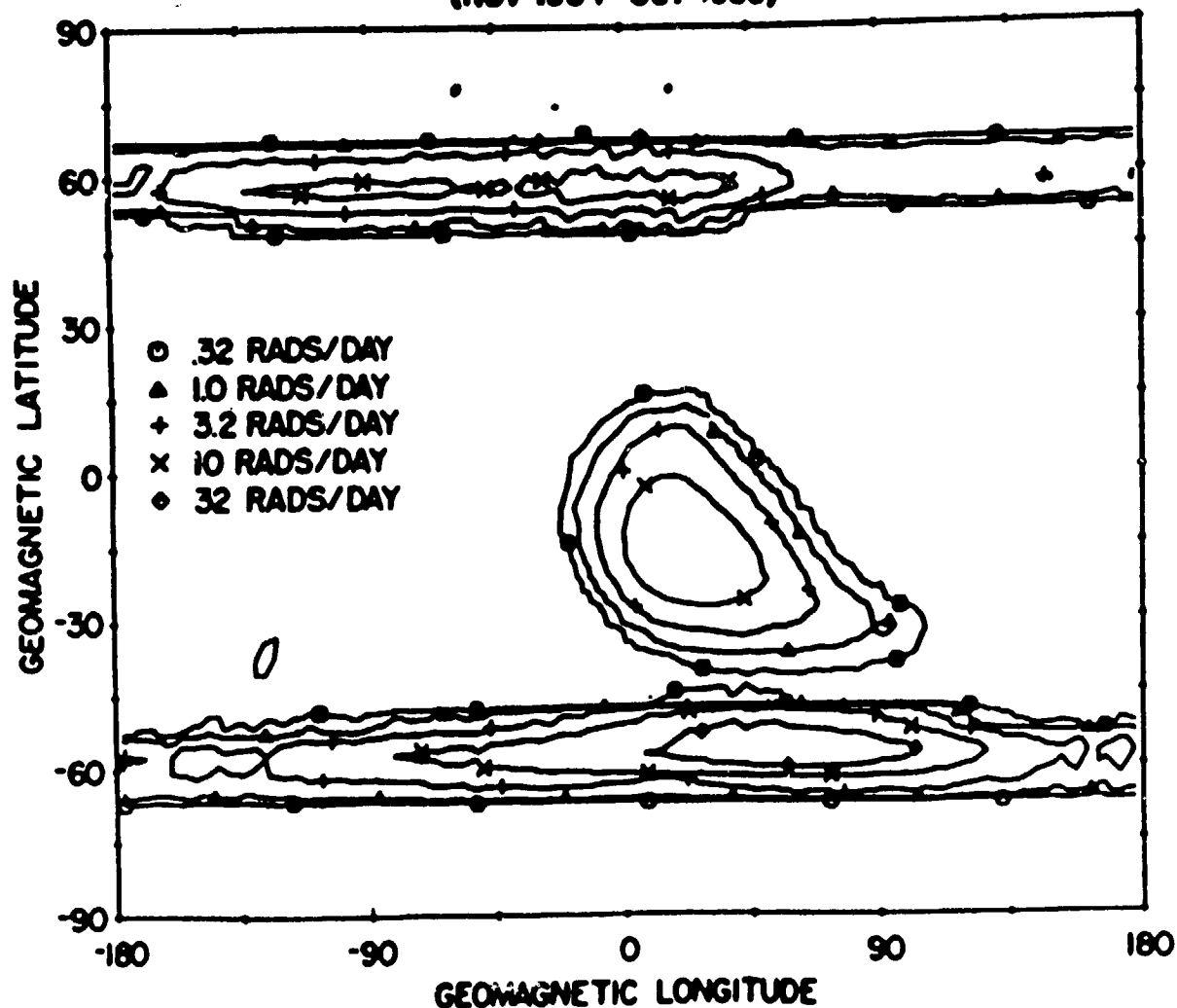


Fig. 1. Map of Energetic Electron Dose as Observed by the DMSP F7 Satellite at Low Altitude Averaged Over One Year (Nov. 1984 - October 1985). In this geomagnetic coordinate system, the horns of the outer radiation belt correspond to bands at geomagnetic latitudes, centered near $\pm 60^\circ$. An additional intense region of particle precipitation (due to the Earth's asymmetric magnetic field) is near longitude 30° in the southern hemisphere as discussed in the text. (From Gussenhoven et al., 1987.)

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